# FORKLIFTS

This document presents project criteria for forklift equipment funding eligibility under the Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program). Also included is an overview of applicable regulations pertaining to forklifts, available control technology, examples of potential projects, and emission reduction and cost-effectiveness calculation methodologies.

## A. Forklift Equipment

Forklifts are used in a wide variety of applications, including, but not limited to, manufacturing, construction, retail, meat and poultry processing, lumber and building supplies, trades, agriculture, and a variety of warehouse operations. Forklifts can be powered by electric motors or by internal combustion engines (ICEs).

The Industrial Truck Association (ITA) has defined seven classes of forklifts. These classes are defined by the type of engine, work environment (indoors, outdoors, narrow aisle, smooth or rough surfaces), operator positions (sit down or standing), and equipment characteristics (type of tire, maximum grade). Several classes are further divided by operating characteristics. The following are the forklift classifications:

- ***Class 1*** are electric motor trucks with cushion or pneumatic (air filled) tires. Class 1 forklifts include four subcategories, or lift codes, which are:

| | |
|---|---|
| Lift Code 1 | Counterbalanced rider type, stand-up |
| Lift Code 4 | Three-wheel electric, sit down |
| Lift Code 5 | Counter balanced rider, cushion tire, sit-down |
| Lift Code 6 | Counter balanced rider, sit-down rider (includes pneumatic tire models) |

- ***Class 2*** forklifts are electric motor narrow aisle trucks with solid tires.

- ***Class 3*** forklifts include electric hand trucks or hand/rider trucks with solid tires.

- ***Class 4*** forklifts are ICE sit down rider forklifts with cushion tires and generally suitable for indoor use on hard surfaces.

- ***Class 5*** forklifts are ICE sit down rider forklifts with pneumatic tires. These are typically used outdoors, on rough surfaces, or significant inclines.

- ***Class 6*** trucks can be either electric or ICE powered. These are ride on units with the ability to tow at least 1,000 pounds. This class is designed to tow cargo rather than lift it.

- ***Class 7*** trucks are rough terrain forklift trucks with pneumatic tires. Class 7 trucks are almost exclusively powered by diesel engines, and are used outdoors.

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## B. Emission Inventory

According to the ARB off-road emissions inventory, there were more than 39,000 ICE forklifts with engines greater than 50 horsepower used in industrial applications in California in 1995. These estimates do not include large terrain forklifts or forklifts used at airport operations. Estimates for forklifts used in airport operations are discussed in the document pertaining to airport ground support equipment. Total NOx emissions from industrial forklifts greater than 50 horsepower in California are estimated to be 62.1 tons per day in 1995, and are estimated to be 37.1 tons per day in 2010. ICE forklifts are fueled with gasoline, propane, natural gas, or diesel.

Table 1 contains ICE forklift population and NOx emission estimates for 1995. The emission estimates for propane, gas and compressed natural gas forklifts have already been approved by ARB. Emission estimates for diesel forklifts are pending Board approval.

**Table 1**
**1995 Population and NOx Emission Estimates**
**For Industrial Forklifts with Internal Combustion Engines**
**California and South Coast Air Basin Data**

| Horsepower Range | Year | Fuel | Population | | NOx Emission (tons per day) | |
|---|---|---|---|---|---|---|
| | | | SCAB | State | SCAB | State |
| 50≤ hp <120 | 1995 | Gasoline | 4,610 | 9,318 | 6.5 | 13.1 |
| 50≤ hp <120 | 1995 | CNG, Propane | 9,914 | 17,638 | 12.3 | 22.0 |
| 50≤ hp <120 | 1995 | Diesel | 4,990 | 10,060 | 10.1 | 19.4 |
| 120≤ hp <175 | 1995 | Gasoline | 168 | 340 | 0.6 | 1.1 |
| 120≤ hp <175 | 1995 | CNG, Propane | 362 | 645 | 1.0 | 1.7 |
| 120≤ hp <175 | 1995 | Diesel | 474 | 956 | 1.5 | 2.9 |
| >175 hp | 1995 | Diesel | 205 | 414 | 1.0 | 1.9 |
| **Total** | | | **20,723** | **39,371** | **33.0** | **62.1** |

The ARB inventory does not contain information on the number of electric forklifts in California. Most of the information on the type of forklifts bought and used is considered to be confidential within the industry. Forklift population estimates that have been developed by Electric Power Research Institute (EPRI) and other sources generally rely on ITA shipment data. Data reviewed by ARB staff indicates that there are about 70,000 electric forklifts in California. Roughly 50,000 of those are the smaller (class 3) hand trucks and narrow aisle trucks, and about 20,000 of those are electric rider forklifts. Electric forklifts have zero exhaust emissions.

## C. Emission Standards

Emission standards for forklifts are contained in ARB and United States Environmental Protection Agency's (U.S EPA) emission standards for off-road equipment. Internal combustion engine forklifts can either be powered by diesel engines (compression-ignited engines) or by spark-ignited engines (which use gasoline, compressed natural gas, or propane fuel). There are separate emission standards for large spark-ignited engines and compression-ignited engines.

Off-road equipment is also split into two broad categories: less than 175 horsepower, and equal to or greater than 175 horsepower. Both of these categories include forklifts. Currently, ARB is preempted from regulating new farm and construction equipment less than 175 horsepower. However, ARB has the authority to regulate off-road equipment equal to or greater than 175 horsepower and non-preempted off-road equipment less than 175 horsepower.

### 1. Large Spark-Ignited Off-Road Engine Standards

Forklifts with spark-ignited engines are commonly used indoors, and typically have lift capacities between 3,000 and 16,000 pounds. A report prepared for the Gas Research Institute indicated that about 45% of spark-ignited forklifts (class 4 and 5) have engines rated 50 horsepower or lower. On an ICE forklift, a 50 horsepower engine generally has a 6,000 pound lift capacity or greater. Propane is the fuel that is most widely used in spark-ignited engines, compared to gasoline or compressed natural gas.

Spark-ignited engines greater than 25 horsepower are classified as large spark-ignited engines by ARB. Current model year large spark-ignited engines are not subject to any ARB or U.S. EPA emission standards. ARB has approved standards for new large spark-ignited off road engines to be implemented beginning with the 2001 model year. The regulations establish exhaust emission standards and test procedures. Table 2 contains the emission standards applicable to large spark-ignited engines that were approved by ARB.

**Table 2**
**Exhaust Emission Standards**
**New Large Spark-ignited Engines**

| Year | Engine Size | NMHC + NOx (g/bhp-hr) | CO (g/bhp-hr) | Durability Period |
|---|---|---|---|---|
| 2002 & later | <1.0 liter | 9.0 | 410 | 1000 hours or 2 years |
| 2001-2003 (Phase-in) | >1.0 liter | 3.0 | 37 | N/A |
| 2004-2006 | >1.0 liter | 3.0 | 37 | 3500 hours or 5 years |
| 2007 & later | >1.0 liter | 3.0 | 37 | 5000 hours or 7 years |

** The standard for in-use compliance for engine families certified to the standards noted above shall be 4.0 gbhp-hr (5.4 g/kW-hr) hydrocarbon plus oxides of nitrogen and 50.0 g/bhp-hr (67 g/kW-hr) carbon monoxide for a useful life of 5000 hours or 7 years.*

### 2. Diesel Off-Road Engine Standards

Compression-ignition engines (diesel) are often used to power forklifts that have large payload requirements. Almost all diesel forklifts have lift capacities over 6,000 pounds, and are available with lift capacities exceeding 40,000 pounds.

Diesel forklifts are subject to off-road compression ignition engine standards. ARB has adopted emission standards for off-road diesel cycle engines equal to or greater than 175 horsepower. The U.S. EPA has adopted NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The U.S. EPA rule aligns with California's first tier regulations for engines 175 horsepower and greater and took effect in 1996. The U.S. EPA rule also took effect in 1997 for off-road diesel cycle engines at or above 100 horsepower but less than 175 horsepower and in 1998 for off-road diesel cycle engines at or above 50 horsepower but less than 100 horsepower. The combination of ARB and U.S. EPA emission standards means that all of today's new off-road diesel cycle engines, including forklifts, 50 to 750 horsepower have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

U.S. EPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. The SOP provides for NOx, PM, and carbon monoxide (CO) emission standards for new engines to be phased-in from 2003 through 2008. U.S. EPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations. Table 3 contains the applicable U.S. EPA standards for off-road diesel engines.

**Table 3**
**U.S. EPA Exhaust Emission Standards for Off-Road Diesel Engines**

| Rated Power (horsepower) | NOx and PM Emission Standards (g/bhp-hr) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1997/8 | | 2003/2004 | | 2007 | | 2008 | |
| | NOx | PM | NMHC +NOx | PM | NMHC + NOx | PM | NMHC + NOx | PM |
| 50 ≤ hp < 100 | 6.9 | -- | 5.6 | 0.30 | 5.6 | 0.30 | 3.5 | 0.30 |
| 100≤ hp < 175 | 6.9 | -- | 4.9 | 0.30 | 3.0 | 0.22 | 3.0 | 0.22 |

## D. Electric Forklifts

Electric forklifts include electric motor trucks with cushion or pneumatic tires (Class 1); electric motor narrow aisle trucks (Class 2); and electric hand trucks or hand/rider trucks (Class 3). Class 1 electric forklifts are available in a wide variety of lift capacities from 3,000 pounds to 20,000 or greater pounds. According to market data evaluated by ARB, most class 1

forklifts sold today in the U.S. are in the 3,000-6,000 pound lift capacity range. There does not appear to have been a large penetration of electric class 1 forklifts with lift capacities greater than 6,000 pounds in the current California or U.S. market.

Electric forklifts are most typically used in indoor materials handling applications that do not require large lift capacities (i.e., warehouse/retail operations). There are some applications where electric forklifts are used extensively, primarily for worker safety. These applications include confined spaces, cold storage, and food retail (primarily grocery stores).

Although electric forklifts are primarily designed for indoor operations, a number of manufacturers are also including equipment features which enable electric models to be used a wider variety of environments. These features include pneumatic tires (air filled), which allow the forklift to be used on unimproved surfaces. Another feature is water proofing trucks or sealing the electronic compartment to make them more water resistant for outdoor conditions. Class 1 forklifts (electric) compete directly with ICE forklifts for many of the same work applications.

Electric forklifts have no exhaust emissions, and extremely low upstream (power plant) emissions. Thus electric forklifts can provide significant air quality benefits. EPRI has prepared several reports on electric forklifts which identify other benefits of electric forklift usage besides improved air quality. One benefit is that electric forklifts have lower life cycle costs when compared with ICE models. This is due to lower maintenance costs, lower fueling costs, and longer useful life for an electric forklift. Although the initial capital cost is higher for an electric forklift as compared with the ICE forklift, the incremental cost can be recouped during the useful life of the electric forklift. Because of the financial benefits to the end user, electric forklifts are already prevalent in the general market.

## E. Control Strategies

Electric forklifts have been widely used for a number of years in the United States. Increasing the use of electric forklifts by replacing ICE forklifts with electric forklifts would reduce NOx emissions. Replacing an older electric forklift with a newer electric model, however, does not reduce emissions. The project criteria for forklifts have been designed to encourage the replacement of an ICE forklift with an electric forklift and to exclude projects where "electric to electric" replacements are likely to occur or where electric forklifts already dominate the market.

### 1. Forklift Class

Class 1 forklifts are the electric models that compete with ICE forklifts because they are similar in design and specification. Class 1 forklifts can be used in many of the same work applications as an ICE (class 4 or 5) forklift. Increasing the use of class 1 forklifts relative to class 4 and 5 forklifts would reduce NOx emissions. Class 2 and 3 forklifts generally do not compete with ICE forklifts. Since these classes are solely electric forklifts, and “electric-to-electric” replacements do not yield NOx reductions, Class 2 and 3 would be excluded from funding under the Carl Moyer Program.

Rough terrain forklifts (Class 7) are primarily powered by diesel engines. Electric or alternatively fueled options are not currently available for Class 7 forklifts. Hence, Class 7 forklifts would be excluded from the Carl Moyer Program.

### 2. Industry Application

The most viable control strategies would include funding electric forklifts that replace ICE forklifts, where electric forklifts are not commonly used. These control strategies would include construction, millwork, cargo handling, lumber, plywood, foundries, and metal work.

Conversely, there are several applications where electric forklifts are used extensively, as compared to ICE forklifts. These industrial applications include confined spaces (such as freezers), cold storage, and food retail (primarily grocery stores). Since electric forklifts are commonly used in these industrial applications, “electric-to-electric” replacements would also be common. Hence, forklift purchases or replacements in industries whose primary business includes confined spaces, cold storage, and food stores are excluded from the Carl Moyer Program.

### 3. Forklift Rental

Market data prepared for the Gas Research Institute indicates several interesting trends regarding forklift usage and ownership. Approximately 55% of Class 1 and 2 forklifts are owned by the end user, 15% are rented (short-term rentals), and 30% are full service leases. The proportion of purchased, rented, and leased ICE forklifts (class 4 and 5) is very similar.

Full service leases are an attractive option to many companies because they reduce the up-front capital costs associated with the purchase of new forklift equipment. Rented and leased-to-own equipment can be deployed in a wide variety of fleets and work applications. There is no practical way to ensure that leased or rented electric forklifts are replacing an ICE forklift, and not an "electric-to-electric" replacement. Therefore, rented and leased equipment is currently excluded under the project criteria

There are a number of issues associated with leased equipment, such as free-ridership (electric-to-electric replacements), enforcement, and incremental capital costs. Due to the lower maintenance and operation costs associated with leasing an electric forklift over an ICE forklift, there can be some cost benefits with leasing an electric forklift. Since reduced costs are already an incentive to the end user, it is hard to determine if an electric forklift would have still been leased without Carl Moyer Program funding as the incentive. Furthermore, it is also difficult to determine the appropriate incremental cost to fund, since an electric forklift may already provide some incentive to the end user. Although leased equipment may seem to be a viable project, it is still necessary to ascertain the conditions under which leased equipment could be incorporated into the Carl Moyer Program. Therefore, only leased-to-own equipment for certain projects would be eligible for funding under the Demonstration Program (discussed later in this document).

### 4. Hours of Usage

The report prepared for the Gas Research Institute also indicates that the annual hours of usage varies significantly between industries. For electric forklifts, the range varies from 500 hours to 3500 hours a year, with an average of about 2,250 hours/year. The average annual hours of usage for an ICE forklift is 1900 hours/year.

The Gas Research Institute report also estimated that two thirds of electric forklifts are purchased new, while one third are purchased used. New electric forklift purchasers often record twice the operating hours as used forklift purchasers. Because of the reduced usage and life expectancy of older equipment, only the purchase of new electric forklifts will be funded under the Carl Moyer Program. In addition, all projects will be required to have an hour meter on each forklift, and track annual hours of operation for the project life (a minimum of five years). This is to ensure that the emission benefits of the project are realized.

### 5. Battery Charger

One good indication that a business or fleet is not currently using an electric forklift is whether they have battery chargers. In order to ensure that the Carl Moyer Program is funding replacement of an ICE forklift with an electric forklift, and not an electric to electric replacement, all projects will be required to purchase battery chargers. The number of chargers purchased must correspond to the number of forklifts purchased. There may be some cases, however, where a charger for every forklift is not necessary. For example, operations that incorporate daily multiple shifts, or facilities that have fast-charging equipment. Applicants showing that there is a need to incorporate an amount of chargers that do not correspond to the amount of forklifts will be evaluated on a case by case basis.

### 6. Multiple Shift Operations

According to the Gas Research Institute, on average, both electric and ICE forklifts operate 1.5 shifts a day, five days a week. Sixty nine percent of class 1 and 2 (electric) forklifts operate one shift a day, 16% operate two shifts, and 15% operate three shifts. According to the survey, on average, an electric (class 1 or 2) forklift is recharged after 11 clock (not meter) hours. Thus, electric forklifts operating in multiple shifts typically use multiple battery packs and battery change out equipment. For ICE forklifts, 59% operate one shift, and almost 40% operate two shifts. The average propane tank is replaced or refilled after 15 hours. Both electric and ICE forklifts can sit idle for a significant portion of the shifts during which they are used. Furthermore, the usage pattern can vary from continual use to 4 or 5 hours per shift. The Carl Moyer Program will fund the purchase of one battery pack per forklift purchased. Applications indicating a request to fund multiple battery packs that may be needed for multiple shift operations will be considered on a case by case basis. Documentation indicating the extensive use will be required.

### 7. New and Expanded Facilities

For new and expanding facilities it is difficult to determine the level of commitment for increasing the purchase of electric forklifts over ICE forklifts. In order for a company with multiple facilities to be funded under the Carl Moyer Program, the company must demonstrate a commitment to significantly increase the percent of electric forklifts over ICE forklifts in the company's fleet. For expanding facilities, companies must demonstrate that the expansion includes a physical change, such as a 25% increase in square footage.

## F. Project Criteria

In order for a forklift project to qualify for funding under the Carl Moyer Program, the project must meet the specific criteria listed below. In general, the incremental cost of all projects must meet a cost-effectiveness criterion of $12,000 per ton of NOx reduced. The forklift must also be operated for at least five years from the time it is first put into operation, and for at least 75 percent of the time in California. Forklift projects that do not meet the specific criteria below, however, may still qualify for funding as a forklift demonstration project (see section G).

- Eligible equipment are four wheel counter-balanced sit-down electric forklifts, rated class 1, lift codes 5 or 6 plus one battery pack for each forklift purchased.

- For existing, new, and expanding facilities, all forklifts must be purchased new, and rated for a minimum lift capacity of 6000 pounds or greater.

- All expanding facilities must provide documentation that indicates a significant physical change in the facility, such as a 25% or greater increase in square feet.

- All eligible projects must also include the installation of battery chargers that correspond to the number of forklifts purchased. Battery chargers are considered infrastructure and cannot be included as project costs.

- All eligible projects will be required to have an hour meter on each forklift, and track annual hours of operation.

- All eligible projects must sign a declaration that the applicant is not replacing an old electric forklift with a new electric forklift.

- For existing facilities, the ICE forklift which is being replaced must have an engine rated for 50 horsepower or greater.

- NOx reductions obtained through this program must not be required by any existing regulations or binding agreements.

- Forklifts used in commercial (passenger) and military airport operations were not included in the forklift emissions inventory. They may be eligible for funding provided they meet both forklift and GSE project criteria.

- All applicants must purchase new forklifts for use by the applicant. Organizations or businesses that rent or lease-to-own are not eligible for funding. Rental or leased equipment costs are also not eligible for funding.

- The following are not eligible for funding under this program: food retail stores, cold storage, and confined space operations (such as freezers).

- The following forklift purchases are not eligible: stand up electric forklifts (class 1, lift code 1), three-wheel electric sit-down rider (class 1, lift code 4), narrow aisle electric forklifts (class 2) or hand/rider trucks (class 3).

## F. Demonstration Program

Purchases of new forklifts with a lift capacity of 6,000 pounds or greater are eligible for funding under the project criteria in Section E. Forklifts under 6,000 pounds lift capacity and leased forklifts are not eligible for funding under the project criteria. The penetration of electric forklifts is higher in the under 6,000 pound lift capacity models, making free ridership (electric-to-electric replacements) of greater concern. There are also a number of concerns regarding leasing as previously discussed. However, forklifts in the 3,000 to 5,999 pound lift capacity range and leased forklifts represent a significant pool of potential projects. Therefore, ARB has proposed a Demonstration Program. Under this program, funds will be available for some applicants that meet the listed Demonstration Program criteria and are replacing ICE forklifts with either new electric forklifts that have lift capacities of 3,000 to 5,999, leased-to-own forklifts, or both.

The purpose of the Demonstration Program will be to gather information about forklift usage, and to gain experience with projects in the 3,000 to 5,999 pound lift capacity range or leased-to-own forklifts. ARB will evaluate the information gained to assess the benefits of these projects, to resolve the outstanding concerns, and to consider conditions for funding these projects under the general program, rather than on a demonstration basis. The Demonstration Program will be a cooperative effort of the air district, the ARB, and a third party (such as an electric utility provider). The third party (i.e. an electric utility provider) will be responsible for collecting data that would be used to determine the benefits of funding these types of projects. The third party (i.e. an electric utility provider) may subcontract the work to be conducted, however the third party would still remain responsible for the quality of the data collected and presented to ARB. Under the Demonstration Program, the third party will be responsible for monitoring the projects and collecting data. Relevant data will include hours of operation (i.e. hours of use, kilowatt-hour use, and hours in idle); the relationship between horsepower and lift capacity; and the cost of charging equipment (including installation) as it impacts the increased market penetration of electric forklifts. In the South Coast, a forklift demonstration program will be implemented with the cooperation of the South Coast Air Quality Management District, Southern California Edison, and the ARB.

Each project funded under the Demonstration Program must meet the following criteria:

- Prior to funding, one or more site visits will be required and will be conducted by the third party. The site visit will include an evaluation of a number of factors, such as: 1) whether or not fuel switching is occurring; 2) whether or not the electric forklift would be replacing an ICE forklift; 3) the customer plans for ICE forklifts that are replaced; and 4) hours of operation. Funding will not be approved if the initial site visit determines that the electric forklifts are replacing older electric forklifts, and not ICE forklifts.

- The third party will also conduct a follow-up site visit to verify that all information provided in the application is correct and project expectations are being met.

- As a condition of funding, the applicant will agree to participate in a monitoring program. This monitoring program will include a few additional items not included in Section I - Reporting and Monitoring. For example, a certain percent of forklifts in the demonstration program will be monitored to determine idling time. The selected percent would be approved by the district to be representative of the group of forklifts monitored. These items will also be monitored for a shorter duration. The parameters listed in Section I, such as hours of usage, amount of electricity used, type and characteristic of charging equipment, and maintenance and repair information will be collected by the third party for a six to twelve month period after purchase. Maintenance costs, lease costs, and the cost of charging equipment (including installation) will also be monitored. The applicant may be asked for one or two electric forklifts outside of the funding program to be monitored (such as used forklifts and 2,000 pound lift capacity forklifts).

- All projects that include leased-to-own equipment must have a signed contract with the air district that specifies the end user will keep and use the equipment for five years.

- The third party in each air district will develop a draft report by September 2000 and a final report in December 2000 summarizing. The report will include data on hours of usage, idling, and kilowatt hours, costs to project participants, and recommendations for how leased-to-own equipment could be incorporated into future project criteria. Data will be presented so that all proprietary and confidential information is protected.

- All projects must meet all Carl Moyer general requirements, which include a minimum project life of five years, a maximum of $12,000/ton cost-effectiveness, and a minimum of 75% equipment operation in California.

## G. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from off-road diesel equipment operators. A sample application form is included in the Appendix. The applicant must provide at least the following information, as listed in Table 4 below:

**Table 4**
**Minimum Application Information**

| | |
|---|---|
| 1. Company name | 12. Project life (min 5 years) |
| 2. Project name | 13. Model & Manufacturer of ICE Forklift Being Replaced (if an existing business) |
| 3. Air district | 14. Estimated annual hours of operation |
| 4. Business or industry of applicant | 15. % operated in California |
| 5. Is the electric forklift replacing an older non-electric forklift, part of operation or facility expansion, or for a brand new facility/operation? | 16. If facility/operation expansion, list current facility square feet and expanded facility square feet. |
| 6. Does the applicant rent or lease forklifts to others? | 17. If new facility/operation, list new facility square ft. |
| 7. Type of forklift purchased | 18. Incentive amount requested |
| 8. Maximum rated lift capacity (in pounds) | 19. Baseline NOx emissions |
| 9. Manufacturer and model number of new forklift | 20. New reduced-NOx emissions |
| 10. Cost of forklift (including 1 battery pack) | 21. Baseline cost (cost for non-electric forklift) |
| 11. Cost of charging equipment purchased | |

## H. Emission Reduction and Cost-Effectiveness

### 1. Emission Reduction Calculation

The emission reduction benefit will be calculated for NOx emissions only and will be determined using the annual hours of operation. Annual NOx emission reductions are determined by multiplying the difference in the NOx emission levels by the rated horsepower of the engine, the load factor, and the hours the engine is expected to operate per year. The load factor is an indication of the amount of work done, on average, by an engine in a particular application, given as a fraction of the rated horsepower of that engine. If the actual load factor is known for an engine it should be used in calculating emission reductions. If the actual load factor is not known, the default value of 0.30 will be used; this is the load factor used in the ARB inventory for all non-construction forklifts (all fuels). Another variable in determining emission reductions is the number of hours the equipment operates. If actual hours of equipment operation are not available, the default value of 1900 annual hours should be used to calculate emission reductions.

**Table 5**
**Baseline Emission Rates for**
**Forklift Engines**

| **Rated Power (horsepower)** | **Type of Engine** | **NOx Emission Rates** |
|---|---|---|
| >50 horsepower | Compression ignition (diesel) | 6.9 (g/bhp-hr) |
| > 50 horsepower | Large Spark-ignited (propane) Uncontrolled | 10.5 (g/bhp-hr) |
| > 50 <120 horsepower | Large Spark-ignited (gasoline) Uncontrolled | 11.8 (g/bhp-hr) |
| >120 horsepower | Large Spark-ignited (gasoline) Uncontrolled | 12.9 (g/bhp-hr) |

## 1. Cost-Effectiveness Calculation

The portion of the cost for an electric forklift project to be funded through the Carl Moyer Program is the difference between the cost of purchasing a new electric forklift and buying a conventional forklift. Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

**Capital Recovery Factor (CRF)** = $\mathbf{[(1 + i)^n (i)] / [(1 + i)^n - 1]}$

Where, $i$ = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for forklift projects are provided below.

## 2. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular forklift project, two examples are presented below. The first example describes the calculations based on replacing a diesel forklift with an electric counter balanced sit down rider electric (class 1) forklift, and the second example shows calculation for the replacement of a propane forklift.

**Example 1 – Calculations for replacement of a diesel forklift, based on hours of operation.** A forklift owner applies for a Carl Moyer Program grant for the purchase of a new counter balanced sit down rider electric forklift to replace a diesel powered ICE forklift. The forklift owner has decided to purchase a new electric forklift instead of purchasing a new diesel forklift certified to a 6.9 g/bhp-hr NOX standard. The cost of the new electric forklift is $39,900, plus $4000 for the battery, whereas the cost to buy a new diesel ICE forklift is $35,730. The new forklift will operate 1900 hours annually and will operate 100 percent of the time in California.

<u>Emission Reduction Calculation</u>

**Annual NOx Reductions (tons/year) =**
**[(Baseline NOx) - (Reduced NOx)] * (Horsepower Rating) * (Annual Operating Hours) * (Load Factor) * (% Op. in CA) * (ton / 907,200 grams)**

Where,

**Baseline NOx Emissions** = Emission level from a new diesel forklift engine: 6.9 g/bhp-hr
**Reduced NOx Emissions** = New electric forklift: 0 g/bhp-hr

| | |
|---|---|
| **Rated Horsepower** | = 90 hp |
| **Annual Operating Hours** | = 1900 hours |
| **Load Factor** | = 0.30 |
| **% Operated in CA** | = 1.0 (i.e., 100%) |
| **(ton/907,200 g)** | Converts grams to tons |

Hence, estimated annual NOx reductions are:
((6.9 – 0) g/bhp-hr) (90 hp) (1900 hours/year) (0.30) (1.0) * (ton / 907,200 g) = **0.39 tons/year**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

| | |
|---|---|
| **Total cost of new electric forklift** | = $39,900 + $4000=$43,900 |
| **Incremental Capital Cost** | = ($43,900 - $35,730=$8,170 |
| **Max. Amount Funded** | = $8,170 |
| **Capital Recovery** | **=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$ |
| **Annualized cost** | = (0.23)($8,170) = $ 1,879/year |
| **Cost-Effectiveness** | = ($1,879/year)/(0.39 tons/year) **= $4,818/ton** |

The project meets the cost-effectiveness limit of $12,000/ton NOx reduced and is eligible for an incentive amount of $8,170.

**Example 2– Calculations for replacement of a propane forklift, based on hours of operation.**

A forklift owner applies for a Carl Moyer Program grant for the purchase of a new counter balanced sit down rider electric forklift to replace a propane powered ICE forklift. The forklift owner has decided to purchase a new electric forklift instead of purchasing a new propane forklift with uncontrolled emissions of 10.5 g/bhp-hr. The cost of the new electric forklift is $30,000 (including one battery pack), whereas the cost to buy a new propane forklift is $25,000. The new forklift will operate 1900 hours annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

**Annual NOx Reductions (tons/year) =**
**[(Baseline NOx) - (Reduced NOx)] * (Horsepower Rating) * (Annual Operating Hours) * (Load Factor) * (% Op. in CA) * (ton / 907,200 grams)**

Where,

| | |
|---|---|
| **Baseline NOx Emissions** | = Uncontolled emission level from a new propane forklift engine: 10.5 g/bhp-hr |
| **Reduced NOx Emissions** | = New electric forklift: 0 g/bhp-hr |
| **Rated Horsepower** | = 60 hp |

**Annual Operating Hours** = 1900 hours
**Load Factor** = 0.30
**% Operated in CA** = 1.0 (i.e., 100%)
**(ton/907,200 g)** Converts grams to tons
L
Hence, estimated annual NOx reductions are:

(10.5 – 0) g/bhp-hr) (60 hp) (1900 hours/year) (0.30) (1.0) * (ton / 907,200 g) = **0.40 tons/year**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

**Total cost of new electric forklift** = $30,000
**Incremental Capital Cost** = ($30,000 - $25,000) =$5,000
**Max. Amount Funded** = $5,000
**Capital Recovery** = $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
**Annualized cost** = (0.23)($5000) = $ 1,150/year
**Cost-Effectiveness** = ($1,150/year)/(0.40 tons/year) **= $2,875/ton**

The project meets the cost-effectiveness limit of $12,000/ton NOx reduced and is eligible for an incentive amount of $5,000.

## I. Reporting and Monitoring

During the project life, a district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new electric forklift projects. This is to ensure that the equipment is operated as stated in the program application. Forklift owners participating in the Carl Moyer Program are required to keep appropriate records throughout the life of the funded project. Records must contain, at a minimum, total hours operated, amount of electricity used, type and characteristic of charging equipment used, maintenance and repair information, and information pertaining to what was done with the ICE forklift that was replaced. Districts could also conduct a scrapping program to ensure what is done with the ICE forklift that is being replaced. All records must be retained and updated throughout the project life and made available at the request of the district.

Districts are also encouraged to closely review applications from applicants who own multiple facilities (i.e. own a chain of facilities) to determine that the applicant demonstrates a significant increase in electric forklift purchases at the new facility versus its existing facilities. Applicants with multiple facilities that are applying for funding at a new facility (additional outlet) would need to provide the district with adequate documentation on the history of forklift purchases for its California facilities. For example, Applicant X owns three outlets in California and is opening a fourth outlet. Applicant X is applying for Carl Moyer Program funding for new

electric forklifts at that fourth outlet. Applicant X would need to provide its forklift purchasing history (i.e. the amount of electric forklifts versus ICE forklifts at each facility) to the district. In this example, the district reviews the historical purchasing data and determines that at facilities 1, 2 and 3 there are 80 percent electric forklifts and 20 percent ICE forklifts. Based on this data, the district would need to review the application for the new facility to determine that the applicant is demonstrating a significant increase in electric purchases over ICE purchases (i.e. 90% electric to 10 % ICE forklifts) at this facility versus its existing facilities. If the applicant demonstrates a significant increase in electric forklift purchases to ICE purchases over its other facilities, then the project could be funded, provided all other criteria are met.